nist
rr

Lockheed

MISSILES & SPACE COMPANY

A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION

SUNNYVALE, CALIFORNIA

HREC-24638
LMSC/HREC D149188

LOCKHEED MISSILES & SPACE COMPANY

HUNTSVILLE RESEARCH & ENGINEERING CENTER

HUNTSVILLE RESEARCH PARK

4800 BRADFORD BLVD., HUNTSVILLE, ALABAMA

CLOSED-CIRCUIT TELEVISION ARC GUIDANCE ADAPTER KIT FOR A COMPUTERIZED WELDING SKATE PHASE I REPORT

September 1969

Contract NAS8-24638

by

K. W. Heimendinger

APPROVED BY:

R. B. Wysor, Supervisor
Advanced Development Section

R. B. Wysor for
A. S. Dunbar, Manager
Systems Engineering Dept.

J. S. Farrior
J. S. Farrior
Resident Director

FOREWORD

This document presents results of the Preliminary Design Study, Phase I, of Contract NAS8-24638 performed by Lockheed's Huntsville Research & Engineering Center for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Alabama. Phase I, performed from 2 June 1969 to 15 August 1969, concludes the first of three phases.

The NASA Contracting Officer Representative (COR) for this contract is Mr. R. A. Taylor of the MSFC Manufacturing Engineering Laboratory with Mr. W. A. Wall, Jr., as alternate.

SUMMARY

Preliminary design of the Closed-Circuit Television Guidance Adapter Kit was completed. The kit consists of four subsystems: (1) an illumination head; (2) viewing optics and illuminators; (3) proximity control system; and (4) wire-feed mechanism. The total kit weighs approximately 12.9 pounds of which 6.5 pounds are suspended on the torch-angle manipulator. This load is not expected to cause any appreciable change to the existing servo systems.

Illumination of the weld seam is provided by a split-bundle flexible light guide with 1/8-inch diameter legs (illuminators). The distance between the illuminators is adjustable between 2 inches and 3-1/4 inches. The illuminators provide at least 1470 centerbeam footcandles at 2 inches distance from the illuminator. The adapter kit is capable of maintaining the illuminators in constant proximity to the work surface while following a 6-inch minimum weld radius at a maximum welding speed of 30 inches per minute.

The viewing optics utilize a single 90-degree viewing prism and lens to view the 2 inches by 3-1/2 inches viewing area. The kit utilizes a single fiberscope bundle, in a very flexible covering, to interface the objective lens mounted on the illumination head to the closed-circuit television camera mounted on the skate. The total viewing optic system provides a minimum resolution of 50 line pairs per millimeter. The single fiberscope bundle with its flexible cover reduces the packing problem and cost of replacement.

The proximity control system utilizes a sensor capable of $\pm$ 0.002-inch tolerance when located 0.100 inch from the work surface. The sensor together with a lightweight direct current micromotor mounted on the illumination head provides precise proximity positioning of the illuminators and viewing optics.

Hardware modifications to the existing torch-angle mainpulator (Modification B) and the wire-feed mechanism are relatively minor. The thicker torch beam and longer beam pivot pin are necessary to provide proper mounting for the illumination head support and wire-feed guide support. No change is necessary in the torch beam bearing. The wire-feed guide support is longer to allow the lowering of the torch mount 2-1/4 inches and to allow the wire-feed mechanism to be mounted below the torch. The wire-feed mechanism's modifications consist mainly of a modified guide and tip. The guide utilizes a 160-degree bend with the same radius as the standard (45-degree bend) with a tip that is twice as long as the standard (3/4-inch). The longer tip reduces the wire curvature being fed to the torch.

This design provides a near optimum adapter kit for adapting the Closed-Circuit Television Arc Guidance system to the torch-angle manipulator and is recommended as the basis for the final design. For the final design the specified 1080 degrees per minute maximum rate-of-rotation of the torch (faster than needed for the worst case of 6-inch minimum weld radius at 30 inches per minute maximum weld rate) needs to be clarified. The gear ratio for the welding torch angle manipulator (Modification B) servomotors needs to be specified.

CONTENTS

Section 1
INTRODUCTION

The expense of holddown tooling for welding double-contour parts and the need for automatic precision welding on the Saturn-IC booster multicell tanks led to the development of a computerized welding skate by NASA/MSFC Manufacturing Engineering Laboratory (MEL). Other research by NASA/MSFC/MEL led to the development of a Closed-Circuit Television (CCTV) arc guidance system. The integration of these two systems would provide a precise and completely automatic method for welding contoured surfaces. The system would be practical and the need for backing tooling and precise skate alignment would be eliminated.

The computerized welding skate and the CCTV arc guidance system have both been proven at MSFC Manufacturing Engineering Laboratory. Under the terms of this contract, Lockheed is developing a CCTV arc guidance adapter kit for the computerized welding skate. The kit will provide an illumination head (light source and CCTV camera viewing optics carrier), fiberscope for remote viewing of the weld seam by the CCTV, precise control of the illumination head, and modifications to the cold-wire feeder and welding head manipulator for total system integration.

In this report, Section 2 contains the preliminary design system description of the CCTV arc guidance adapter kit. Sections 3 and 4 contain the considerations and analysis of major components used in the preliminary design. Section 5 contains the changes necessary to adapt the kit to the existing Modification B torch-angle manipulator. Conclusions and recommendations are presented in Section 6.

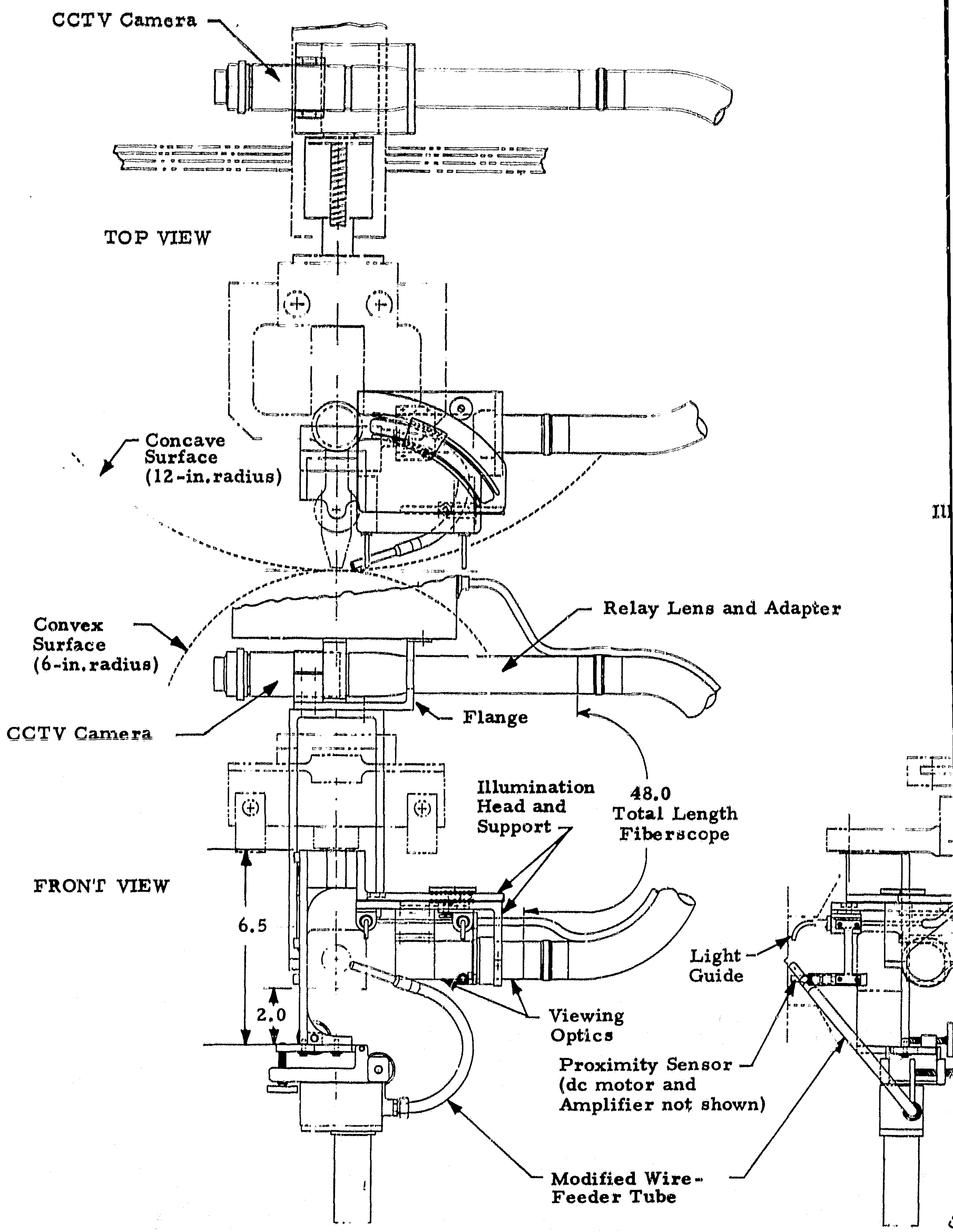
Section 2
SYSTEM DESCRIPTION

The system described herein is the CCTV Arc Guidance Adapter Kit developed for the computerized welding skate. The illumination head (light source and viewing optics platform), viewing optics, proximity control system, and cold-wire feeder compose the four major subsystems to the kit and are shown in Fig. 2-1. Although each subsystem is discussed separately, their combined interaction causes the guidance system to function properly. Modifications to the existing torch-head manipulator needed in addition to Modification B are discussed in Section 3.2.

2.1 ILLUMINATION HEAD

The illumination head serves primarily as a platform for the light sources (illuminators) and viewing optics. The illuminators must maintain a constant distance from the work piece in order to provide proper seam illumination. The viewing optics must maintain a constant focus on the illuminated seam. This is accomplished by maintaining the illumination head a fixed distance from the seam. Thus, by mounting the illuminators in a fixed configuration in relation to the viewing optics and then maintaining the illuminators at the proper distance from the seam, both jobs are accomplished with a single platform and single control system. The illumination head also serves as a platform for the proximity sensor, the dc motor, and reduction gears.

The illumination head (Fig. 2-1) is a plate which rotates -29 deg to +16 deg about a center of rotation 13/16 in. forward of the center of rotation of the torch head. The illumination head rotates independently of the torch head. This is necessary so that the illuminators maintain a constant proximity from the work piece for all specified conditions. This includes minimum work curvature radii (Ref. 1) of 6 in. (15 cm) when the torch is



FOLDOUT FRAME I

Note: All dimensions are in inches.

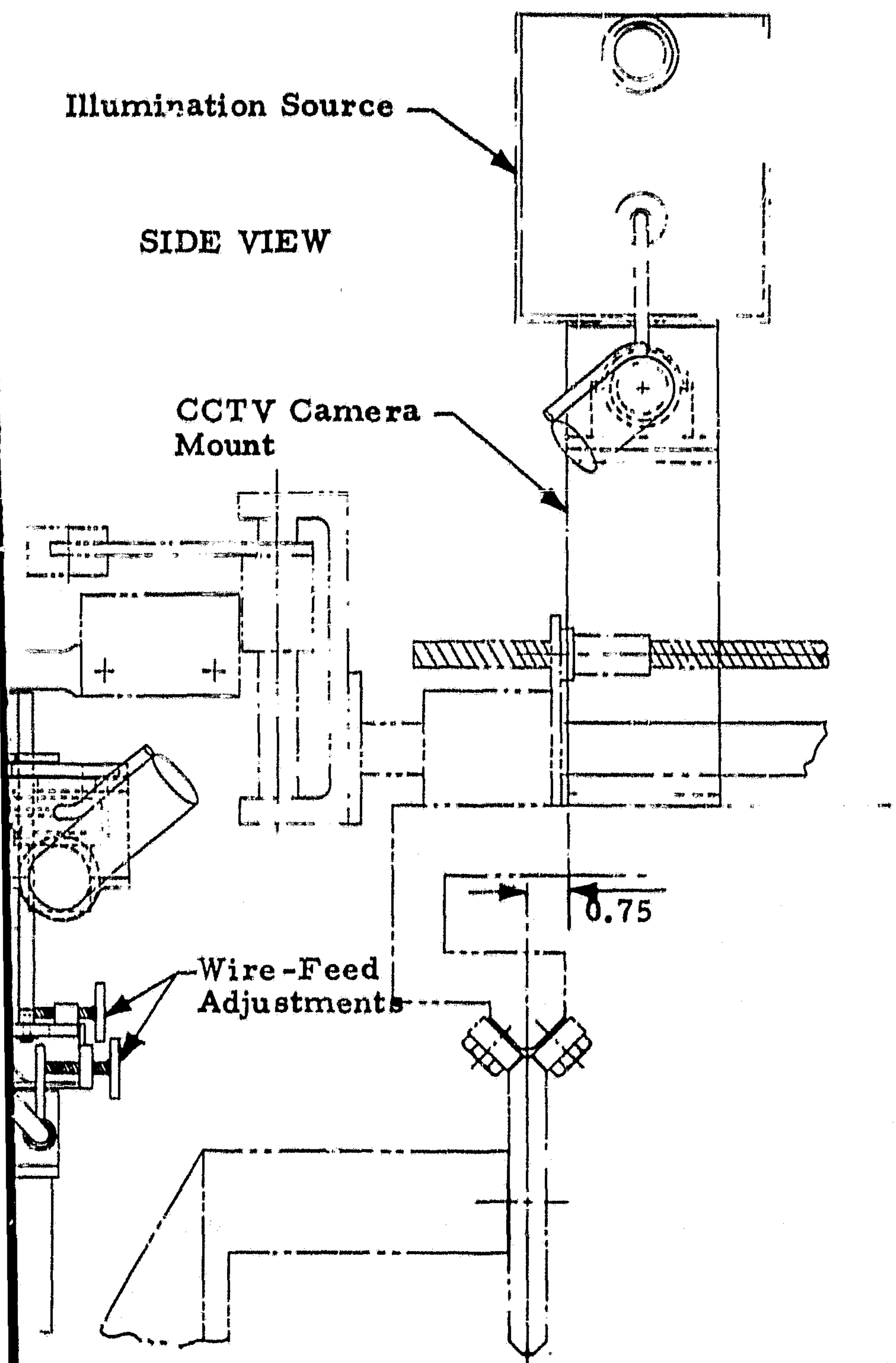


Fig. 2-1 - CCTV Arc Guidance Adapter Kit Configuration located on the convex side of the work as shown in Fig. 2-3a and of 12 in. (30 cm) when the torch is located on the concave side of the work as shown in Fig. 2-3b. The torch head will rotate $\pm$ 40 deg so as to remain perpendicular to the work surface while following the work curvature. However, the torch head can travel $\pm$45 deg from stop to stop. Allowances have been made in the illumination head rotation to prevent illuminator damage should the head exceed the $\pm$40 deg rotation (Ref. 2) and travel to the stop.

The illumination head support (Fig. 2-2) mounts to the torch beam and has gear teeth (45-deg arc segment of 12-in. diameter gear) cut into its edge to engage the 3/4-in. diameter drive gear. The illumination head is supported through a slot in the illumination head support by a ball bearing race which moves along grooved tracks on either side of the slot. Thus, the drive gear drives the illumination head along the tracks. The reduction gears and dc motor are mounted rigidly to the illumination head.

The aft illuminator located 1 in. from the torch is the primary illumination source for the guidance system. The forward illuminator is adjustable from 2 in. to 3-1/4 in. from the aft illuminator. It is used as an alternate guidance source when the work piece is tack welded prior to final welding. The adjustment between illuminators is necessary to span the length of the tack weld.

The two illuminators (Fig. 2-4) will be provided by a split-bundle flexible light guide six feet long, with two 1/8-in. diameter legs. The split bundle, together with a standard commercially available illumination source, provides proper light intensity. Illumination intensity from such a system will be 1470 centerbeam footcandles measured 2 in. from the end of each of the 1/8-in. diameter legs. The 1/8-in. diameter legs will be metal clad at the ends with a 75-deg bend as shown in Fig. 2-1. This provides the specified incident angle on the weld joint for proper illumination. The illumination source mounts next to the CCTV camera on the welding skate yoke. The flexible light guide is routed along the fiberscope to the skate.

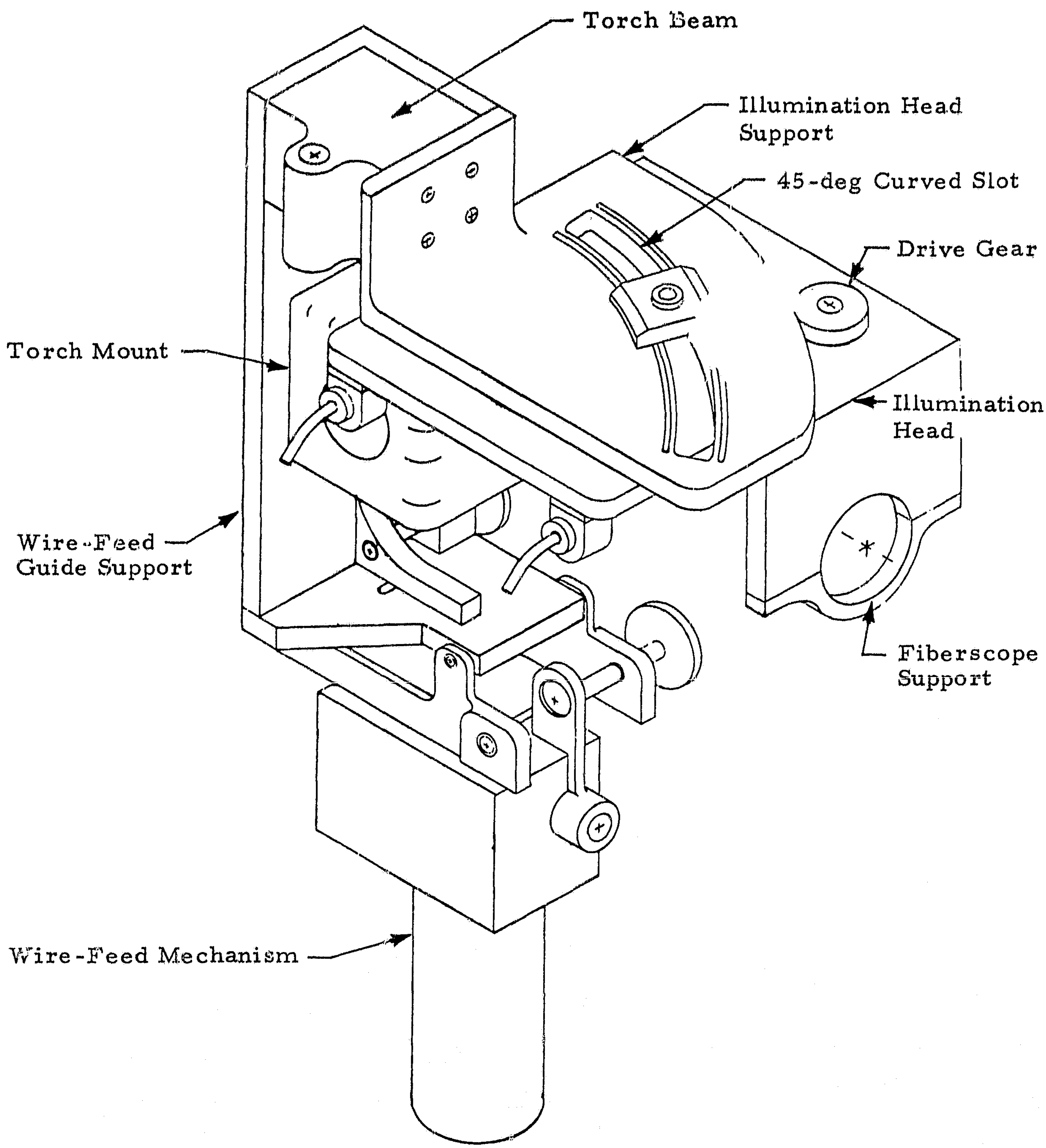


Fig. 2-2 - CCTV Guidance Adapter Kit Without Viewing Optics

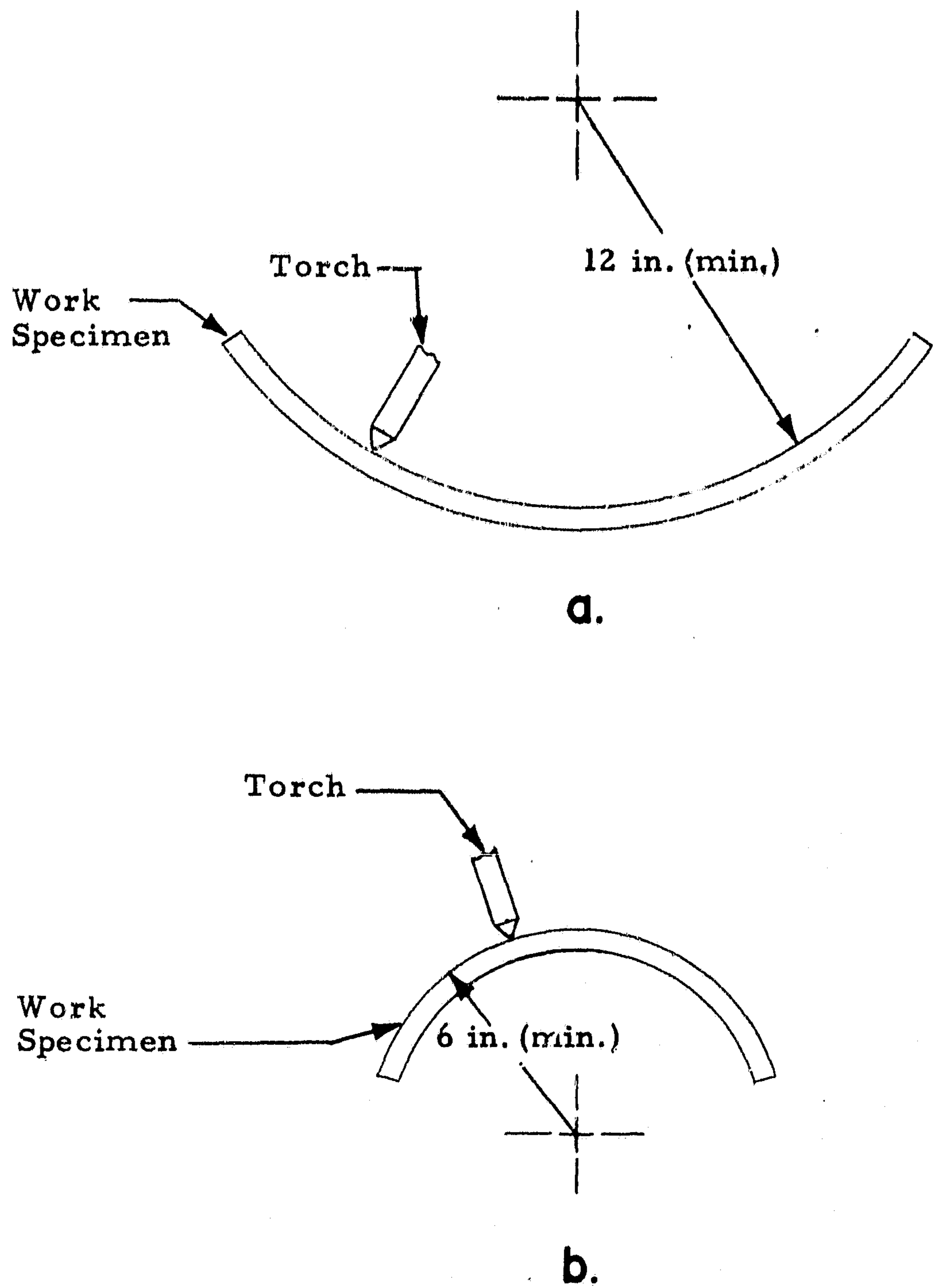


Fig. 2-3 - Minimum Work Curvatures

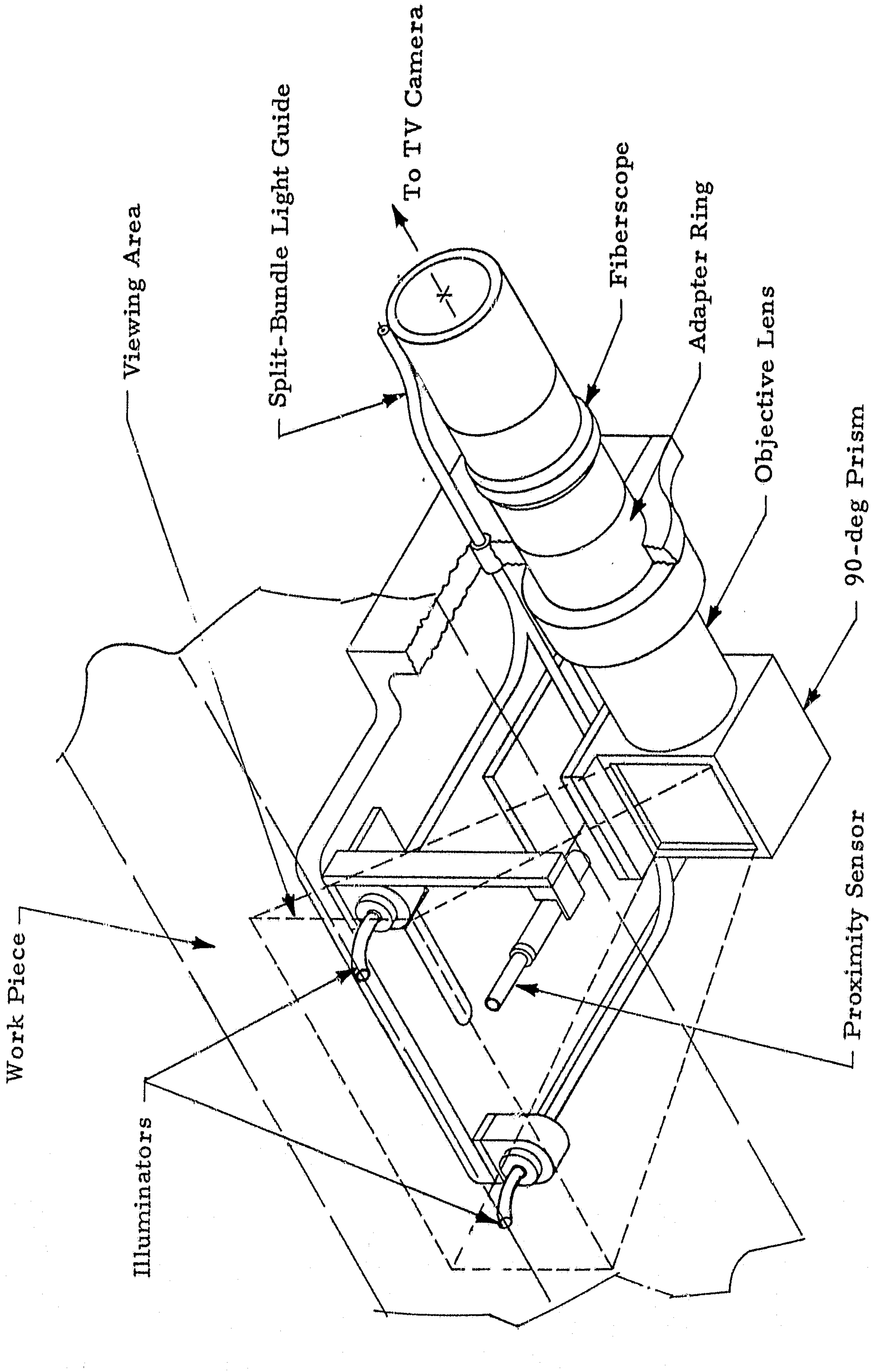


Fig. 2-4 - Viewing Optics and Light Guides

2.2 VIEWING OPTICS

The viewing optics for the CCTV arc guidance adapter kit monitors a 2-in. x 3-1/2-in. seam area 7/8-in. in front of the torch. Mounting the viewing optics rigidly to the illumination head 4 in. from the seam provides the proper object distance and continuous focus of the viewing area.

The viewing optics, as shown in Fig. 2-4, consists of a 90-deg viewing prism, one objective lens with an adapter ring for mating to the fiberscope, and a single-bundle fiberscope four feet long. The relay lens and adapter (Fig. 2-1) interface the fiberscope with the "D" lens mount of the CCTV camera as shown in Fig. 2-1. The standard single-bundle fiberscope provides a minimum resolution of 50 line pair per mm and an 8-mm format. It also offers two advantages over the original split-fiber bundle: ease in packaging the kit and lower replacement cost should the original be damaged. The fiberscope covering will be similar to a plastic-covered spiral-wire vacuum cleaner hose. This offers the flexibility of a polyvinylchloride (PVC) covering and the protection offered by the standard stainless steel braid.

The CCTV camera is a General Electrodynamics ED 6038A television instrumentation camera with a 1/2-in. vidicon head. The camera is 1-1/2-in. o.d., 5-3/15-in. long, excluding the lens, and weighs 14 oz. The fiberscope adapter is threaded to conform to the "D" mount on the camera. A 1/4-in. threaded flange is provided in front of the camera. The adapter attaches to the camera through the flange. The flange takes any stress and torque transmitted through the fiberscope. The camera mount (Fig. 2-1) is located 3/4-in. outside the track centerline on the skate yoke. This allows the camera to be mounted over the actuator area and to face the direction of travel.

2.3 PROXIMITY CONTROL SYSTEM

Figure 2-5 shows the proximity control system block diagram. An Electro Products Model 4947A miniature proximity sensor and modified Model 55.121 proximity amplifier provide an analog signal voltage. This

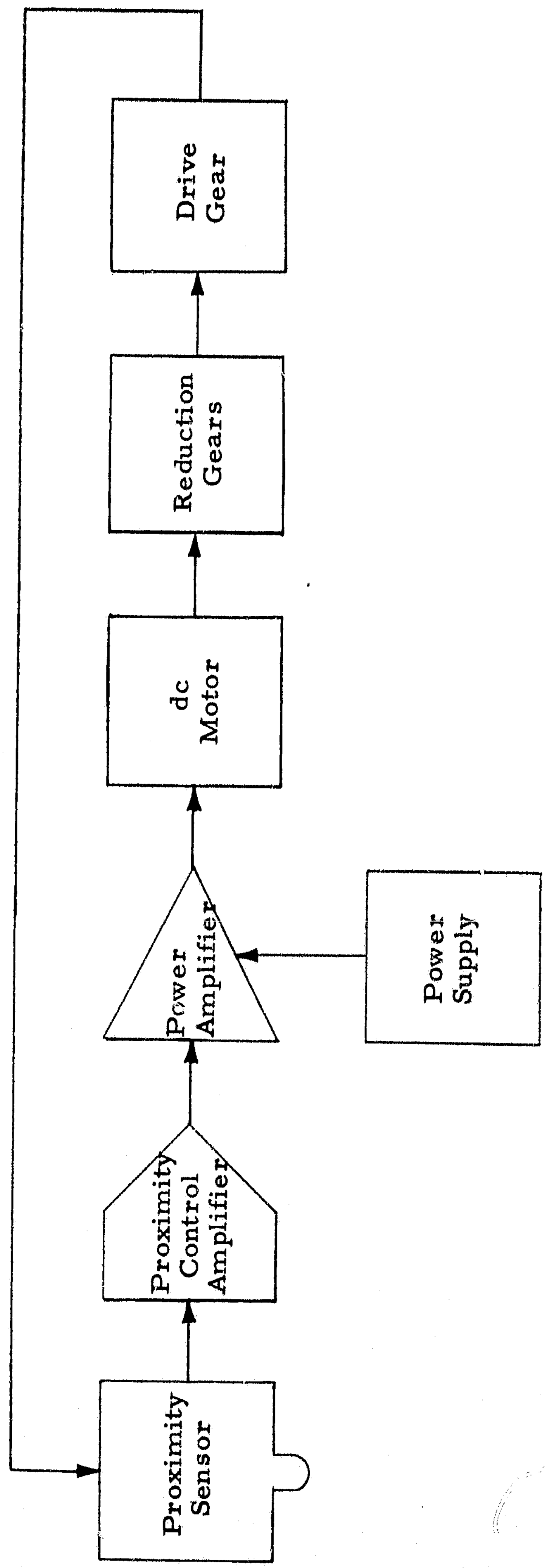


Fig. 2-5 - Proximity Control System

voltage is used to position the illumination head. The proximity sensor (Fig. 2-1) is rigidly connected to the forward illuminator. Both the sensor and forward illuminator lie in a plane perpendicular to the weld seam. Thus, they both have the same 2-in. to 3-1/4-in. adjustment from the aft illuminator. The sensor and the illuminators maintain a position of 0.100 in. from the work surface. Signal amplification and power necessary to drive the dc motor are provided by Opamp Laboratory's operational amplifier Model 415 and power supply Model 523. A Portescap Escap 15 dc motor with 486:1 slip-on reduction gear provides the power to the drive gear on the illumination head. The motor is lightweight and measures 3/4-in. diameter by 1-9/16-in. long, including the reduction gears. Thus, it mounts directly to the drive gear on the illumination head and eliminates the need for a flexible drive shaft.

2.4 WIRE-FEED MECHANISM

The Airco Model HMF-A-2304-0300 wire-feed mechanism must be properly positioned with respect to the torch in order to feed the wire into the weld. This positioning requires modifications to the location of the feed mechanism, as well as to the feed mechanism itself. As shown in Figs. 2-1 and 2-2, the wire-feed mechanism is located 6-1/2-in. below the compensator beam and 2 in. below the torch mount. The wire-feed guide feeds the wire to the torch at the specified 18-deg angle on the side opposite the illuminators. This minimizes illumination interference. The position of the wire-feed mechanism and guide relative to the torch remains constant for all maneuvers of the torch. The modified feeder provides fine positioning adjustments as does the standard feeder. Further modifications to the feeder include removing the plastic motor casing to increase clearance of the feed mechanism with respect to the rail support. A small plastic cover provides sufficient electrical protection. Small gauge wires (routed along the fiber optics) connect the wire-feed motor to the skate terminal board. This eliminates the loading on the wire-feed mechanism by the heavy gauge industrial wire. The heavy gauge industrial wire connects the terminal board to the wire-feed controller. The modified wire-feed guide has a 3-in. radius bend, the same as that of the standard guide. The modified guide contains a 160-deg bend while the standard contains only a 45-deg bend. The tip of the modified guide is twice as long as the standard tip to provide straightening of the wire after the 160-deg bend. Reflective interference is minimized by finishing the wire-feed guide and tip with a flat black finish.

Section 3
OPTICS CONSIDERATIONS

The illumination and viewing optics systems were anticipated to be a straightforward design problem. The original concept centered around two viewing lenses to view the total viewing area. A readily available split-bundle fiberscope enhanced this concept and reduced the CCTV camera interface problem. The confined working envelope and required maneuverability of the illumination head, however, were not compatible with the bulk and stiffness of the split-bundle fiberscope. Numerous telephone discussions with the optics vendor were not adequate in obtaining a workable viewing optics system. The need for direct contact between engineering personnel required a trip by Lockheed personnel for an engineering conference, Ref. 3. At the conference a workable system evolved as shown in Fig. 2-1.

3.1 VIEWING OPTICS

The viewing optics require a resolution of 50 line-pairs per mm minimum, an 8-mm format, and the ability to view a 2-in. x 3-1/2-in. seam area. The size of the viewing area with the confined working space suggested two possible approaches – prisms (or mirrors) or fiber optics. Both techniques were to use two lenses to view the seam area.

The prism system, as shown in Fig. 3-1, was abandoned after study showed that:

1. Object distances and focal lengths of available optics were not compatible for obtaining an adequate system for the CCTV to view.

2. There was not adequate room for mounting the CCTV camera below the torch-angle manipulator.

3. Motion compensation would be more complicated if viewing field distortion was to be eliminated.

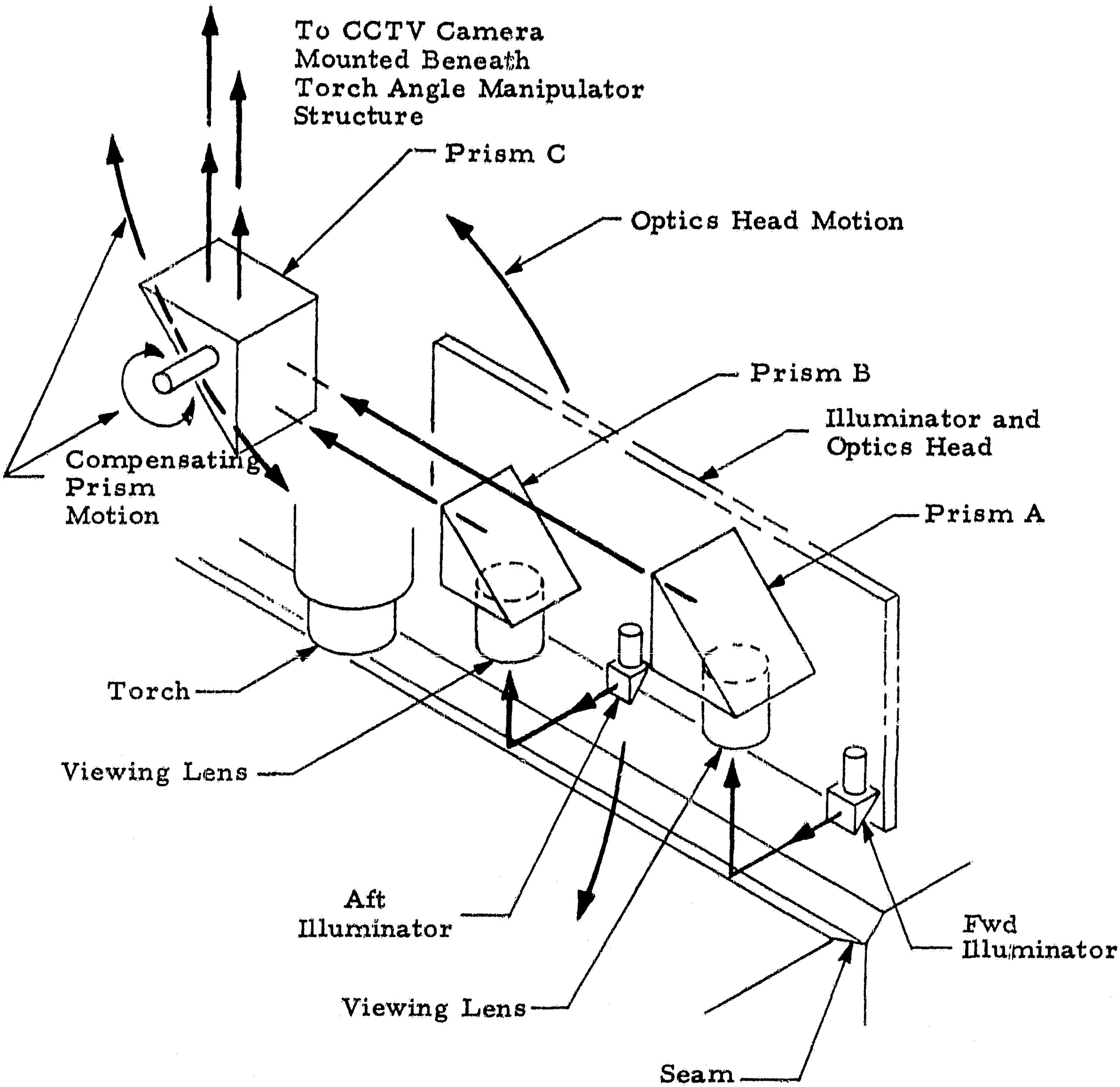


Fig. 3-1 - Seam Viewing Optics — Prism Configuration

The second technique, as shown in Fig. 3-2, utilizing two lenses with fiberscopes was pursued. A split-bundle fiberscope was available on special order and ideal for use with the two-lens technique. This allowed the camera to be mounted on the skate. Standard lenses with an object distance of 2-in. that were compatible with the fiberscope were not available; however, two compatible lenses with object distances of 4-in. were found. Positioning the optics and fiberscope within the working envelope was impossible unless a 90-deg bend within the envelope could be accomplished. The minimum bend radius of the fiberscope coupled with the fixed dimensions of the optics prevented this. The fact that there were two of everything to be fitted in the small envelope complicated the problem.

The question as to whether a workable optics system under the present design could be worked out led to a trip by Lockheed personnel to the American Optical Company plant for an engineering conference (Ref. 3). At the conference, it was determined that a split-bundle, two-lens system was not feasible. However, a system utilizing some of the concepts from both original approaches was developed. It consists of a single 90-deg viewing prism rigidly mounted to the illumination head 4-in. from the work surface, a single-lens, a single-fiberscope bundle, and the proper relay lens and adapters. This system has a minimum resolution of 50-line pairs per mm, an 8-mm format, views the total 2-in. x 3-1/2-in. seam area and automatically maintains focus on the light spots. It also offers simplicity in packaging within the available working envelope and a low replacement cost should the original fiberscope become damaged.

It was also determined that the fiberscope needed a more flexible covering than that offered by the standard braided stainless-steel covering. This reduces the torque loading on the illumination head. Many coverings were investigated. The one chosen is similar to a plastic-covered, spiral-wire vacuum cleaner hose. This affords both the flexibility and the protection neede.

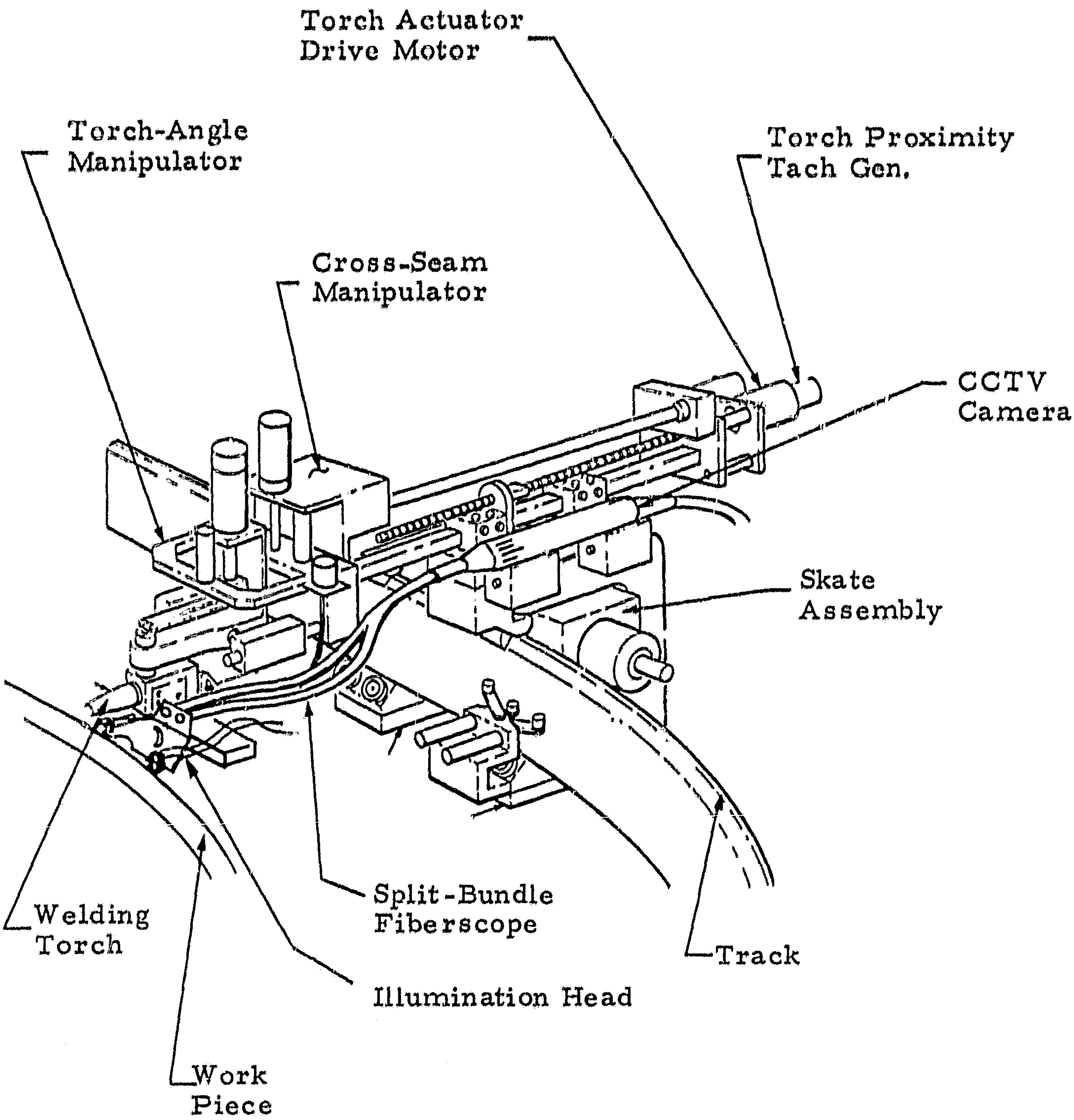


Fig. 3-2 - Split-Bundle Fiberscope Configuration

The CCTV camera (Fig. 2-1) is mounted on the skate over the rail and oriented to face the direction of travel of the skate. This reduces the torque loading on the CCTV camera as well as the illumination head. By use of a 1/4-in. threaded flange in front of the CCTV camera, the fiberscope torque loading is transmitted through the adapter threads to the flange instead of the camera.

3.2 ILLUMINATION SOURCES

Proper illumination of the seam requires a minimum light intensity of 1000 centerbeam footcandles at a distance of 2-in. from the end of the source. The distance between light sources must be adjustable from 2-in. to 3-1/4-in.

The possiblity of using lens tip incandescent lamps on the illumination head was investigated. Several commerically available tungsten lamps with rated end candlepower of 3800 to 5000 footcandles were tested. They are operated at rated voltage of 16V to 48V. To use these lamps and maintain the proper incident angle, custom-made image conduit with a 75-deg bend must mate to the lamp. To replace a burnt-out lamp, the image conduit must be locked firmly in place and not be bonded to the lamp. This imposes packaging problems since the lamps are large and do not have close tolerances on length. Thus, they would have to be completely enclosed in a large custom-made holder. The concentrated power inside the holder would make it excessively hot. This would be apparent on changing a burnt-out bulb or adjusting the distance between sources.

The present technique in use, fiberoptic light guides, was also investigated. A split-bundle light guide 6-ft long with two 1/8-in. legs offers the best system (Fig. 2-4). Used together with a single illuminator, it offers a variable intensity up to 1470 center-beam footcandles (Fig. 3-3) when measured 2-in. from the end of the light guide. The two 1/8-in. legs have metal-clad ends, each with a 75-deg bend. Thus, a simple clamp holds the light guide in place. The light source will be mounted on the skate above the CCTV camera, with the same orientation. The light guides are easily routed out of the way with the CCTV fiberscope bundle.

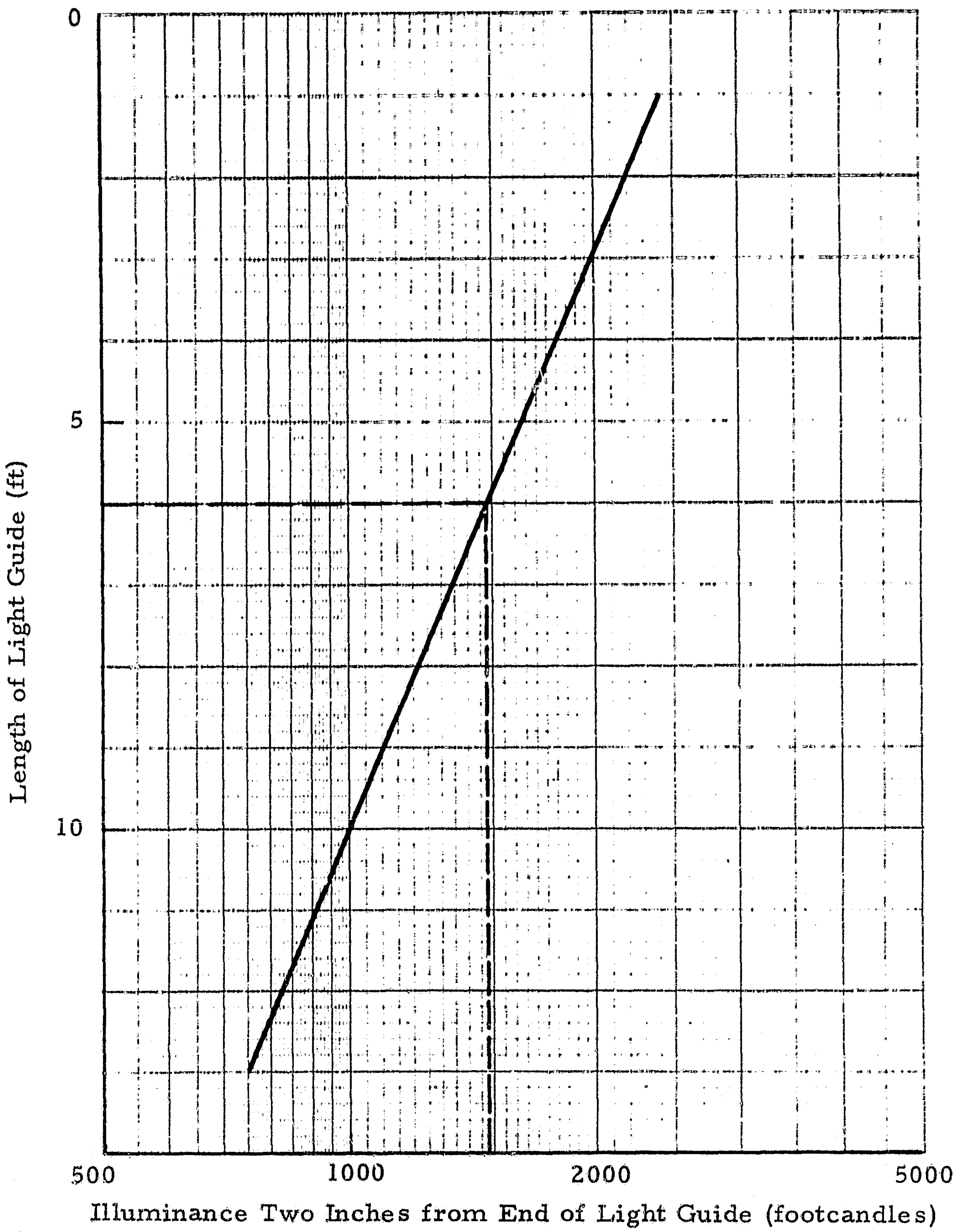


Fig. 3-3 - Illumination at a Surface by the AO K150 Illumination Source and the AO 1/8-Inch Diameter Light Guide

Section 4
CONTROL SYSTEM ANALYSIS

The analysis of the control system was divided into three tasks: (1) determine actuator requirements to drive the illumination head; (2) choose a dc motor with proper reduction gear ratio (gear motor) to drive the actuator; and (3) choose a proximity sensor system with adequate control power to drive the motor.

4.1 ACTUATOR DESIGN

To find an actuator to drive the illumination head, it is first necessary to determine the center of rotation and the amount of rotation of the illumination head. The illuminators must maintain a constant proximity to the work for a minimum work curvature radii of 6 in. (15 cm) when the torch is located on the convex side of the work as shown in Fig. 2-3a and of 12 in. (30 cm) when the torch is located on the concave side of the work as shown in Fig. 2-3b. The maximum amount of rotation occurs between the concave radius and the convex radius when the illuminators are fully extended (3-1/4 in. apart). This is shown in Fig. 4-1. The center of rotation of the illumination head is located 13/16 in. in front of the torch. For the convex radius, the illumination head rotates -25 deg. For the concave radius, the illumination head rotates +12 deg. Rotation allowances of -29 deg to +16 deg provide a margin of safety for the illuminators and the drive system.

A cam slot in the illumination head support (Fig. 2-2) provides the +16 deg to -29 deg rotation about the proper center of rotation. To drive the illumination head with minimum mechanical loss, a 1/4-in. diameter linear actuator (ball screw) was investigated. To prevent mechanical binding, the axis of the linear actuators must lie tangent to the arc traced by the point where the actuator connects to the illumination head. This required position

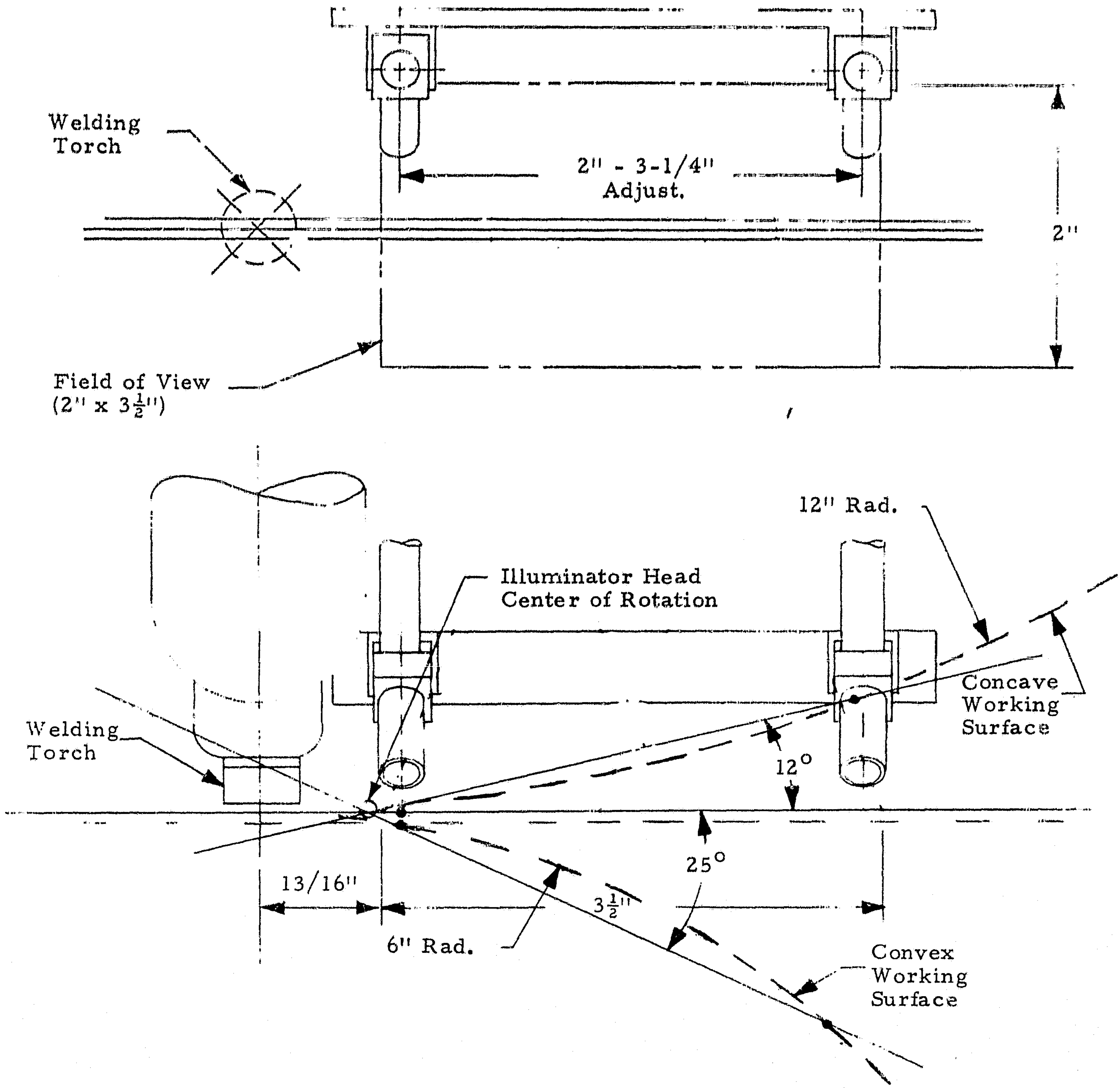


Fig. 4-1 - Welding Adapter Viewing Area

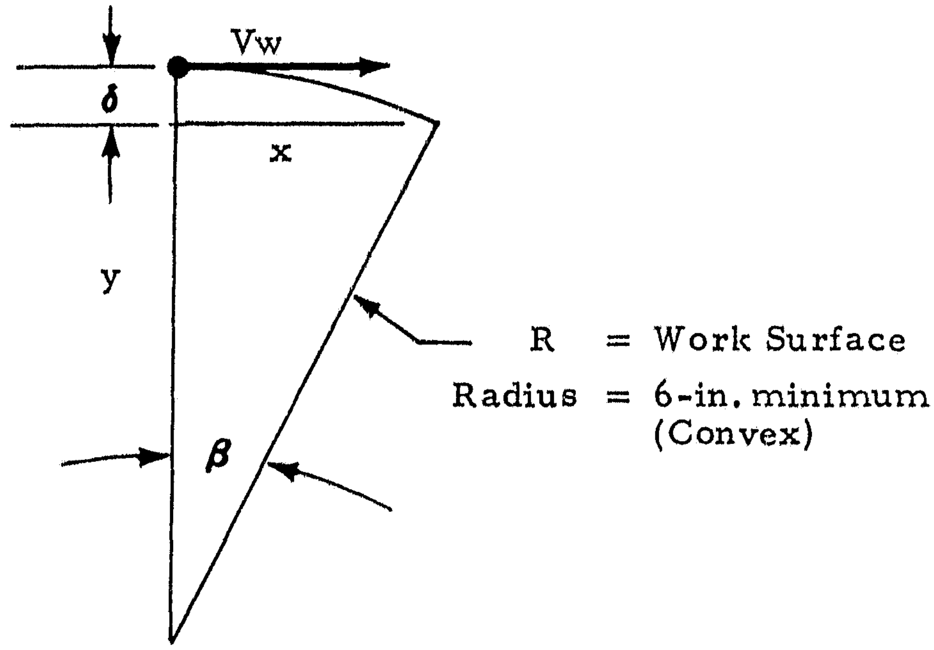
plus the length of the linear actuator to drive the illumination head to the -29-deg extreme results in a length of actuator extending 5 in. in front of the illumination head when welding a straight surface. Direct interference between the fiberscope and the actuator would result. Such interference would lead to catastrophic damage to one or both. The viewing optics orientation cannot change if the optics are to stay within the limits of the working envelope. Thus, either the linear actuator had to be repositioned or a new type actuator found. Repositioning the linear actuator would result in mechanical binding or create interference problems. Thus, a new type of actuator was needed.

The rotation of the illumination head about a center of rotation lends itself to a gear actuator. Gear teeth are cut in the edges of the illumination head support for a 45-deg arc located 6 in. from the center of rotation (12-in. diameter gear). The drive gear attached to the illumination head engages this gear and moves the illumination head along the cam slot (Fig. 2-2). The drive gear is only 3/4-in. in diameter. This small gear easily fits into the space available and provides a 16:1 gear ratio. The use of precision gears keeps the mechanical loss to that of the linear actuator. The actuator is now compact with no interference problems.

4.2 GEAR MOTOR REQUIREMENTS

Determining the response time, torque and speed of rotation necessary to drive the illumination head was the first step in selecting the proper gear motor (dc motor with slip-on reduction gears). The design proximity tolerance, δ, assumed to maintain the optics in proper focus is ± 0.020 in. This tolerance should not impose design problems for the optics system and should be reasonable for the illuminator head control system. The response time necessary to maintain this tolerance at a maximum welding speed of 30 in./min (Ref. 2) is found from Fig. 4-2 and as follows:

$$\Delta t = \frac{R \sin \beta}{Vw} = \frac{0.491 \text{ in.}}{0.5 \text{ in./sec}} = 0.983 \text{ sec.}$$



$$\cos\beta = \frac{y}{R} = \frac{5.98}{6.00} = 0.966 \text{ for } \delta = 0.020 \text{ in.}$$

Fig. 4-2

The loads on the system are composed of friction, inertia and bending moment. The bending moment is induced by the stiffness of the casing of the fiberscope. The weight of the illumination head is 3.5 lb which effects the system through the friction loading only. To overcome this friction of the system in moving the illumination head requires a torque of 2.7 in.-oz output from the gear motor.

The maximum rotation speed occurs under worse case conditions; i.e., the system welding at maximum weld speed abruptly changes from a 12-in. concave surface to a 6-in. convex surface (see Fig. 2-3). The illumination head begins to rotate at the tangent of the curves, while the torch travels an additional 22-deg arc of travel in 9.22 sec before reaching the tangent point. Thus at 30 in./min maximum welding speed, the illumination head must rotate at a rate of 4.8 deg/sec from

$$\omega = \frac{44.2 \text{ deg max. rotation}}{9.22 \text{ sec}} = 4.78 \text{ deg/sec}$$

Also, the corresponding gear motor output must be 13 rpm.

Attaching the gear motor directly to the illumination head and drive gear eliminates the need for a flexible drive and a mounting location on the skate. To accomplish this requires a small-size motor. Such a gear motor is an Escap 15 micromotor with type C-15 metal slip-on reduction gears. The motor with a 486:1 gear ratio cam provides 19.4 in.-oz output at 18.5 rpm. The inertia torque of the system with this gear ratio is 6.24×10^{4} in.-oz from the following equation.

$$T = I\alpha = \frac{I\,(Vw^2)(G.R.)}{R \sin\beta \; (r_{d.g.})}$$

This torque has a negligible effect on the starting time of the motor, which is 0.06 sec.

The Swiss-made, precision, gear motor requires 2 Vdc at 0.5 amp maximum (1 watt), weighs 2.6 oz and costs less than $35.00. The additional 17.2 in.-oz available from the motor is capable of handling 220 in.-oz bending moment about the illuminator head center of rotation. This appears to be a reasonable allowance for torque induced by the fiberscope hardware.

4.3 SENSOR AND ELECTRONICS SELECTION

The control system performs properly if the proximity sensor has the required sensitivity and response. Although 360 degree-of-freedom rollers can do the job, the electronic proximity sensor is preferred. Not only is it more sensitive and faster in response, but it does not have to be in contact with the work piece. Thus, workpiece preparation is minimized.

Such an electronic proximity sensor is the Electro Products model 4947A maniature proximity sensor, together with the model 55.121 proximity control amplifier. The proximity sensor is 1/4-in. diameter and 1-1/2-in. long. Its sensitivity is ±0.002 in. at 0.100 in. from the work which is approximately 10 times the required sensitivity. Unit cost is less than $25.00. The proximity control amplifier must be used to energize the sensor. It also provides a control relay. The control relay does not provide adequate control since this system requires proportional voltage control to the motor to maintain the ±0.002-in. tolerance. Only an analog signal voltage can accomplish this. Modifying the model 55.121 control amplifier by tapping the analog control voltage to the relay switching transistor provides an analog voltage signal of 0.16 Vdc to 2.71 Vdc. However, the current available is only tenths of a milliampere whereas the motor requires 500 milliamperes maximum. Using an operational amplifier with power supply similar to Opamp Labs Model 415 and Model 523 respectively, provides sufficient power to the motor. Cost of the operational amplifier and power supply is less than $60.00 total.

Section 5
MECHANICAL ANALYSIS

The CCTV arc guidance adapter kit for the existing Modification B Torch-Angle Manipulator and skate was analyzed to determine the effects on the existing servo system and any necessary changes to the existing hardware.

5.1 SERVO SYSTEM EFFECTS

Table 5-1 presents a summary of the increased loading on the existing servomotors caused by the weight and configuration of the adapter kit. The servomotors on the manipulator are affected by the 104-oz weight of the adapter kit. The increased friction and torque on the skate motor is induced by the 104-oz eccentric load of the adapter kit plus the weight of the CCTV camera and illumination source mounted on the skate. This total weight is 206 oz. The increased torque loads on the manipulator servomotors are small enough that their effect on the servomotors should be negligible. This analysis will be refined as required during final design.

5.2 HARDWARE MODIFICATIONS

Modifications to the existing torch-angle manipulator (Modification B) include the torch beam and beam pivot pin, the torch mount, and the wire-feed guide support as shown in Fig. 2-2. The increased load of the adapter necessitates a thicker torch beam and thus a longer beam pivot pin. The new torch beam accommodates the wire-feed guide support and the illumination head support. The increased load will have no appreciable effect on the torch beam bearing. The physical size and required locations of the illuminators and viewing optics necessitate the lowering of the torch mount 2-1/4-in. below its original position. Lengthening the wire-feed guide support accommodates the lowering of the torch mount. It also allows the proper positioning of the wire-feed mechanism below the torch.

Table 5-1

INCREASED SERVOMOTOR LOADING

Motor	Added Weight	Induced Moment	Friction	Total Increased Motor Torque Load
Skate	206 oz*	Not Computed	Not Computed	Additional torque induced by 206 oz eccentric load
Cross-Seam Manipulator	104 oz	NA	nil	1.15 in.-oz
Torch-Angle Manipulator	104 oz	416 in.-oz	nil	0.91 in.-oz
Torch Actuator	104 oz	NA	nil	2.30 in.-oz

*Includes 104-oz adapter kit plus CCTV camera, illumination source, partial fiberscope weight, and CCTV camera adapter and relay lens.

Section 6
CONCLUSIONS AND RECOMMENDATIONS

A dependable and accurate CCTV arc guidance adapter kit has been designed and it is recommended that this preliminary design be accepted and used as the basis for the final design.

In order for the final design to be accomplished, additional information is needed. The specifications (Ref. 1) call for the maximum rate of rotation of the torch to be 1080 deg/min. However, this rate appears unnecessarily fast to be compatible with the specified 6-in. minimum radius and the maximum welding rate of 30-in./min (Ref. 2). Thus clarification as to the proper maximum rate of rotation of the torch is needed. Also, the gear ratios for the welding torch-angle manipulator (Modification B) servomotors need to be specified. Assembly Drawing No. MR&T sk-801B only states "As Required."

REFERENCES

1. Wall, W. A., "Specification MR&T-sk-1214, Criteria for the Integration of a CCTV Arc Guidance System with a Computerized Welding Skate," Marshall Space Flight Center, Huntsville, Ala., 1969.

2. Dunbar, A. S., "Contract NAS8-24638, CCTV Arc Guidance Adapter Kit for a Computerized Welding Skate, Monthly Progress Report," LMSC/HREC D149115, Lockheed Missiles & Space Company, Huntsville, Ala., 16 July 1969.

3. Conference at Southbridge, Mass. between Mr. Kip Heimendinger of Lockheed/Huntsville and Mr. Roy Miller and Mr. Bob Durward of American Optical Company, 6 August 1969.